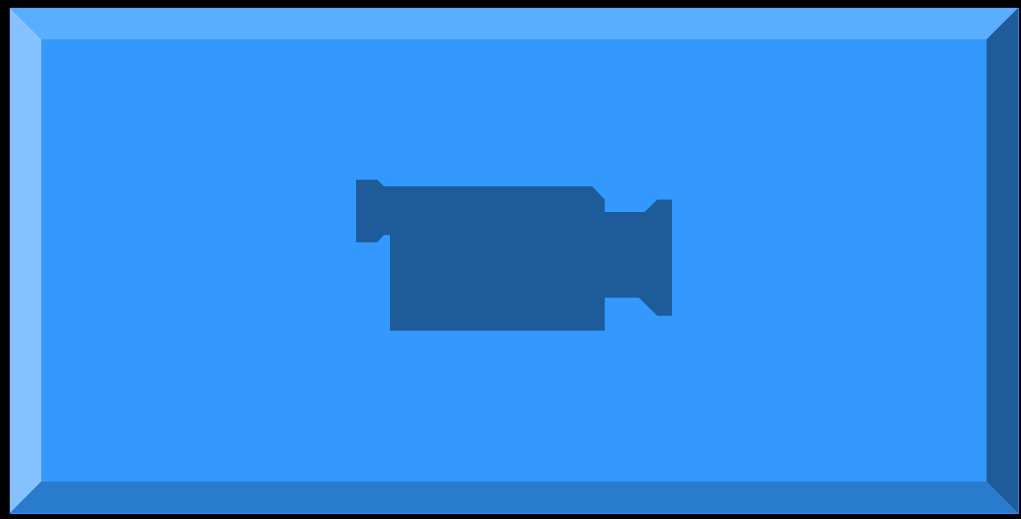
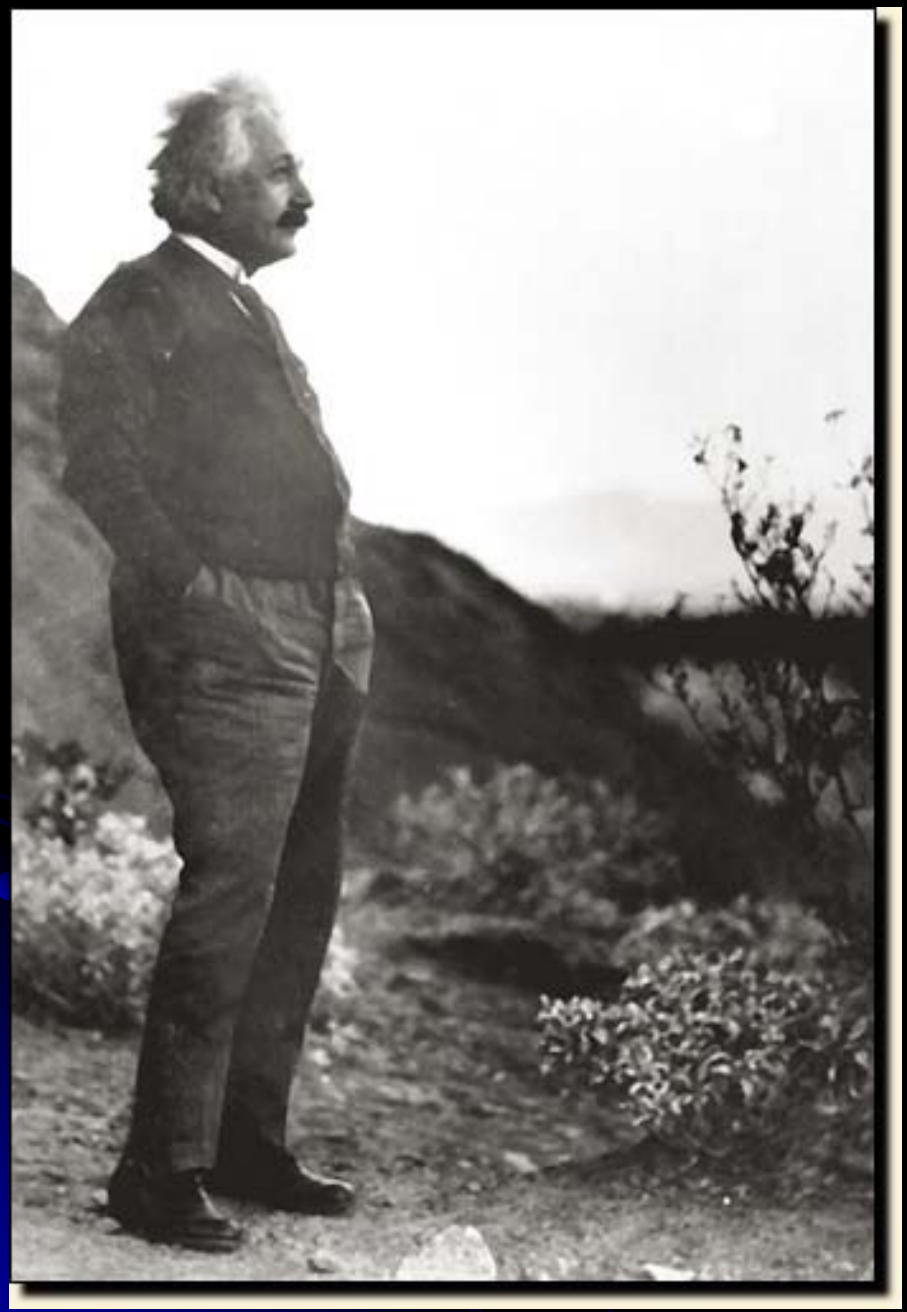
Introduction to Fermilab

SIST Program
Fermilab

Pier Oddone, 6/6/06



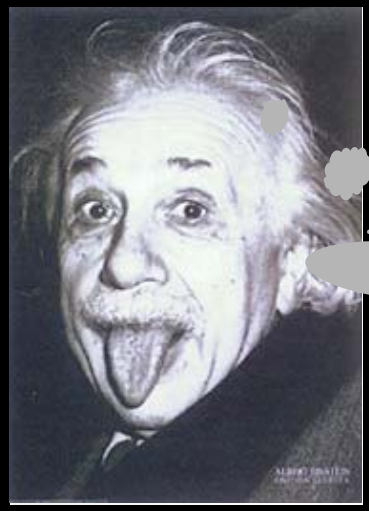


- The most beautiful experience we can have is the mysterious.
- It is the fundamental emotion which stands at the cradle of true art and true science.

Not just expanding: accelerating!

Supernova 1994D
In NGC 4526
(Virgo Cluster)
HST Image

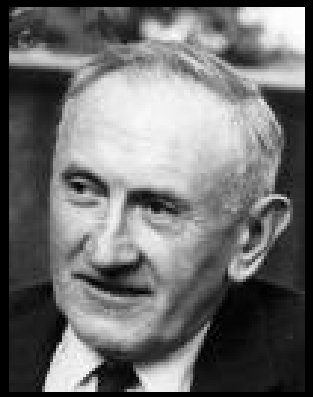
The Cosmological Constant



$$H^2 = \frac{8\pi G\rho}{3} - \frac{k}{a^2} + \frac{\Lambda}{3}$$

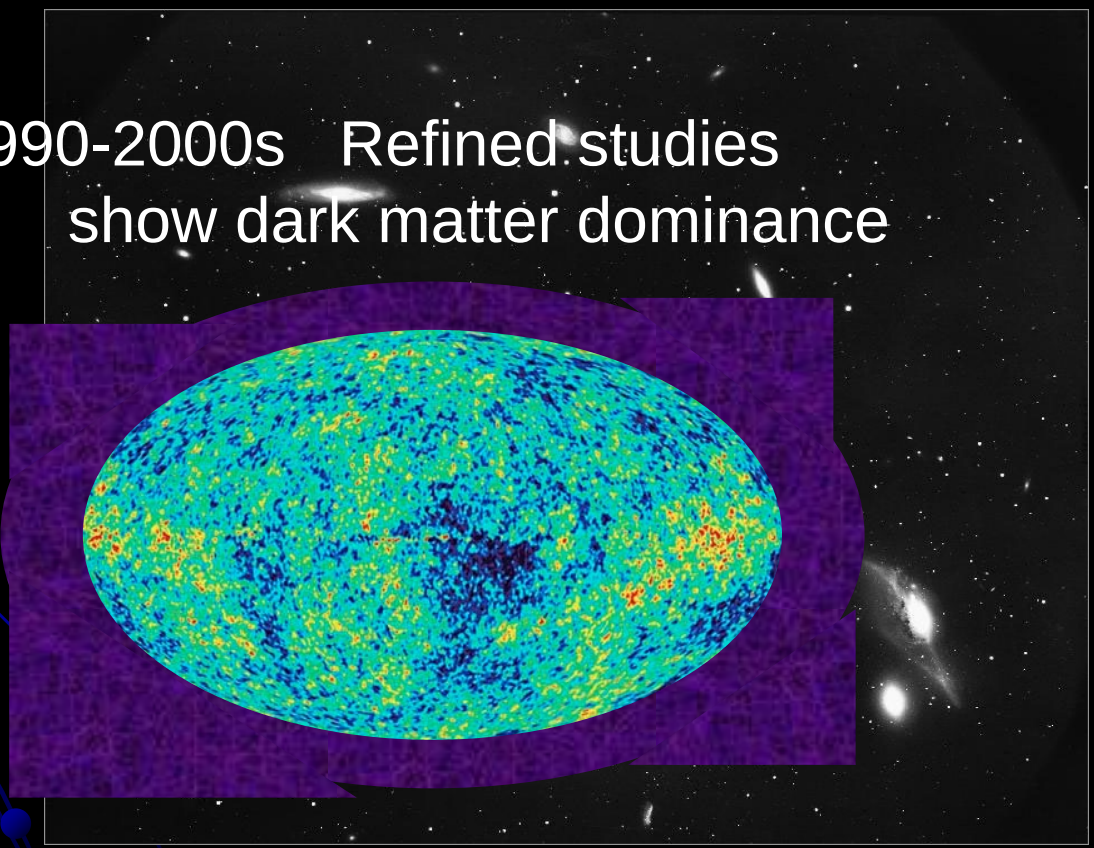
- Einstein put a cosmological constant Λ (vacuum energy) into his equations of GR to allow for a static universe.
- By tuning Λ, attractive gravity due to matter density can be balanced by the “repulsive” gravity, or negative pressure, of Λ
- Danger! Runaway solution if Λ is large and positive!

Dark Matter Evidence

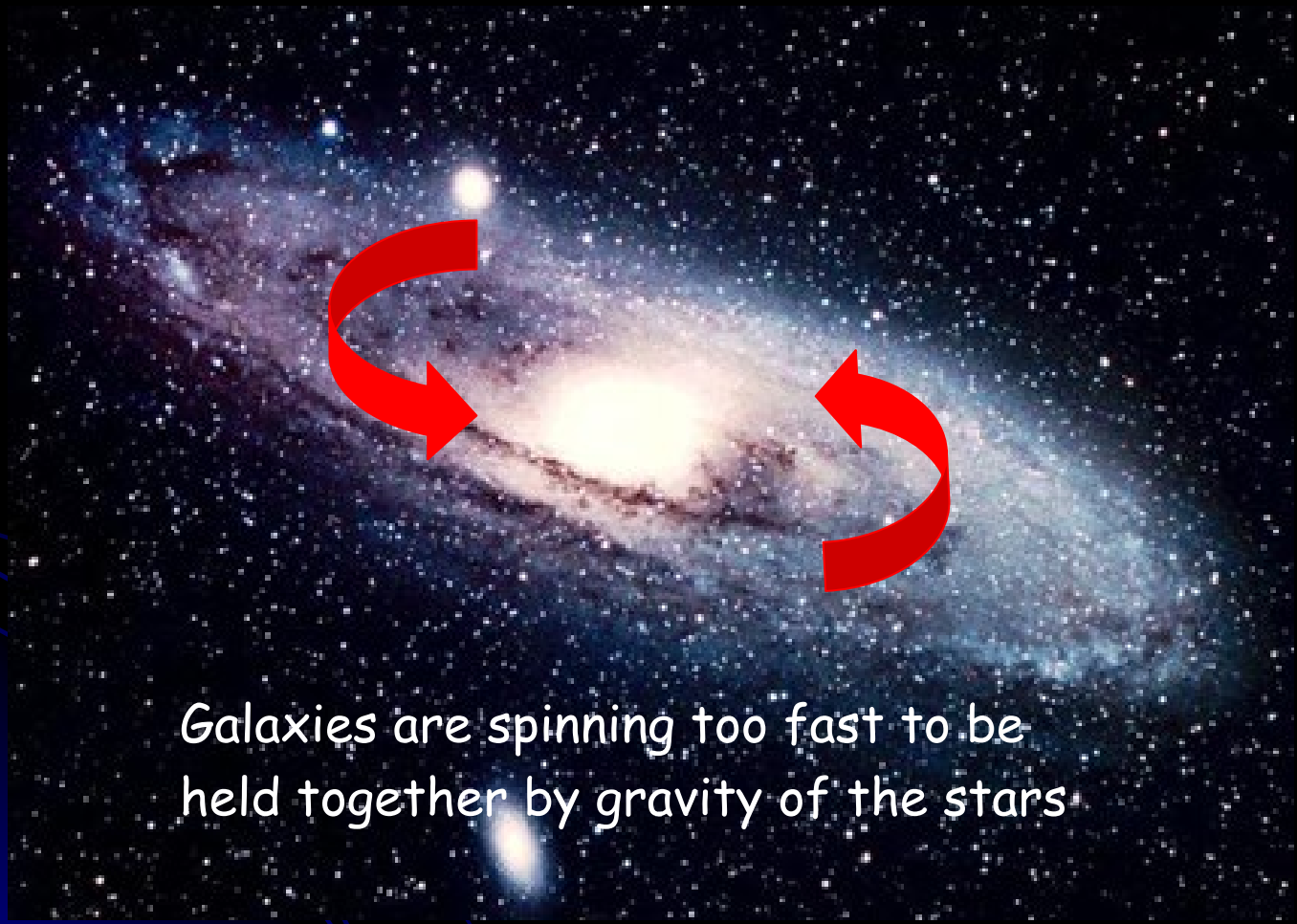


- 1930s motions of clusters of galaxies cannot be understood – Fritz Zwicky

- 1990-2000s Refined studies show dark matter dominance

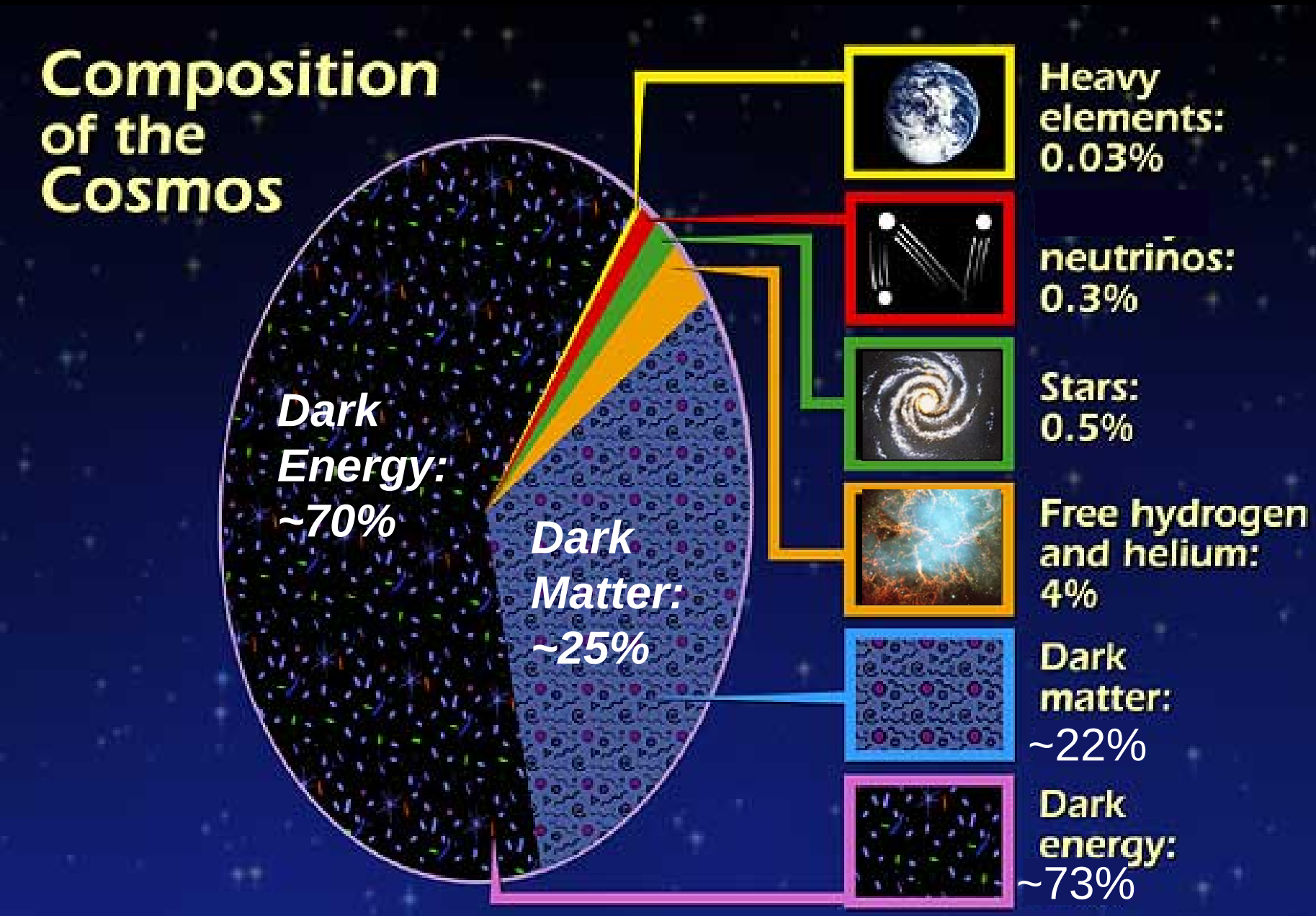


How do we know that galaxies are surrounded by dark halo?



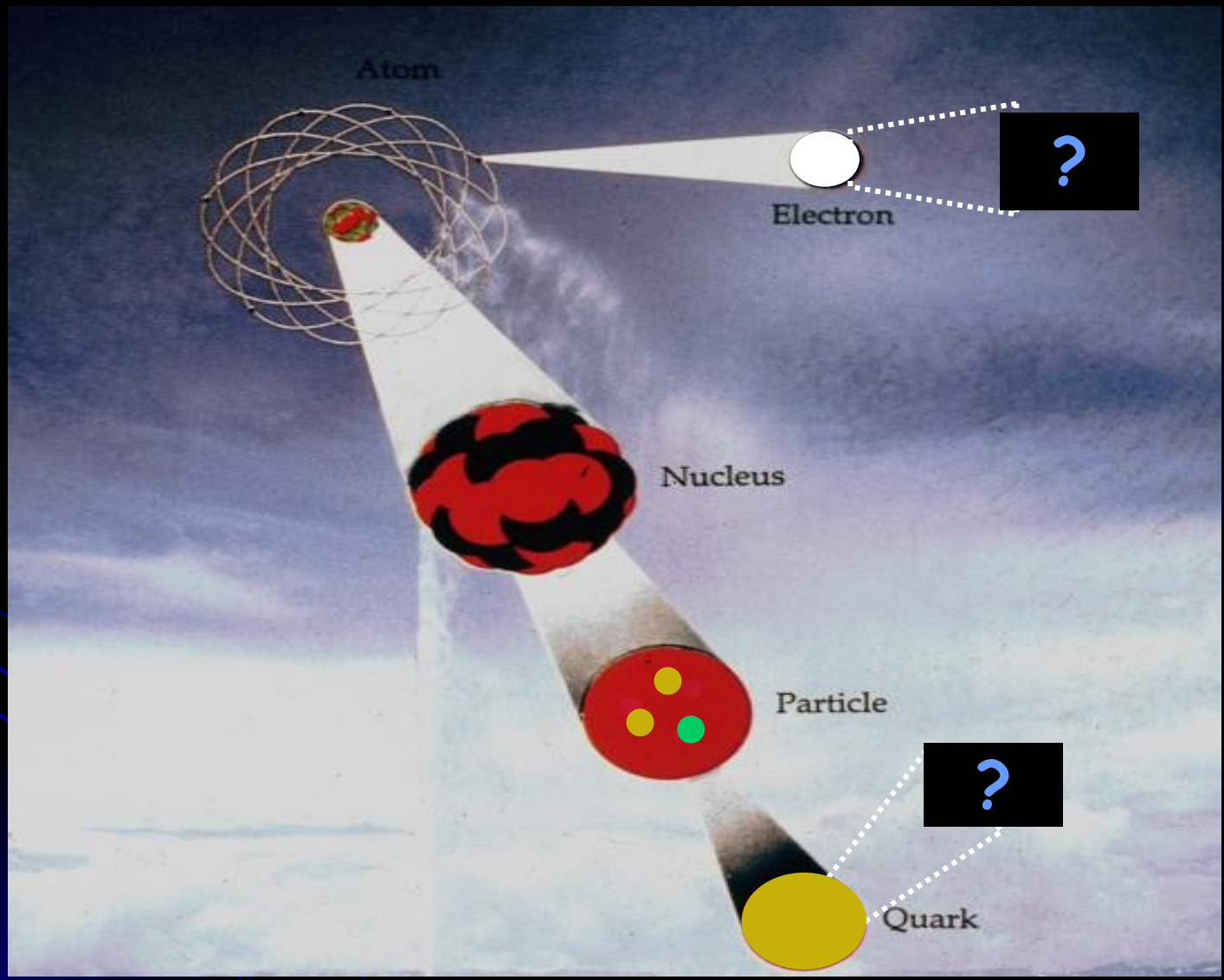
Vera Rubin
1950s

Energy budget of Universe



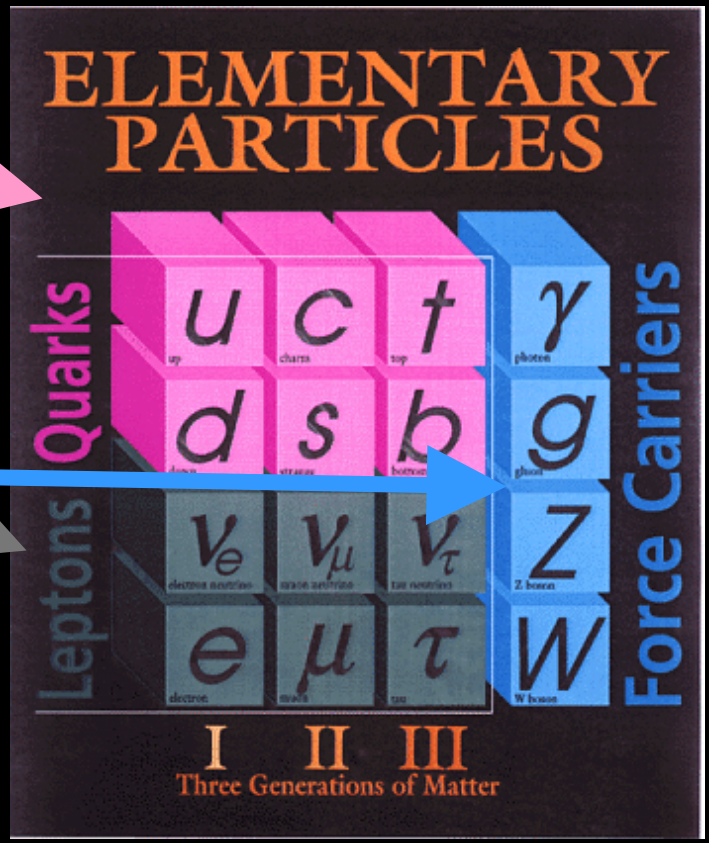
Our Mysterious Universe

The Structure of Matter

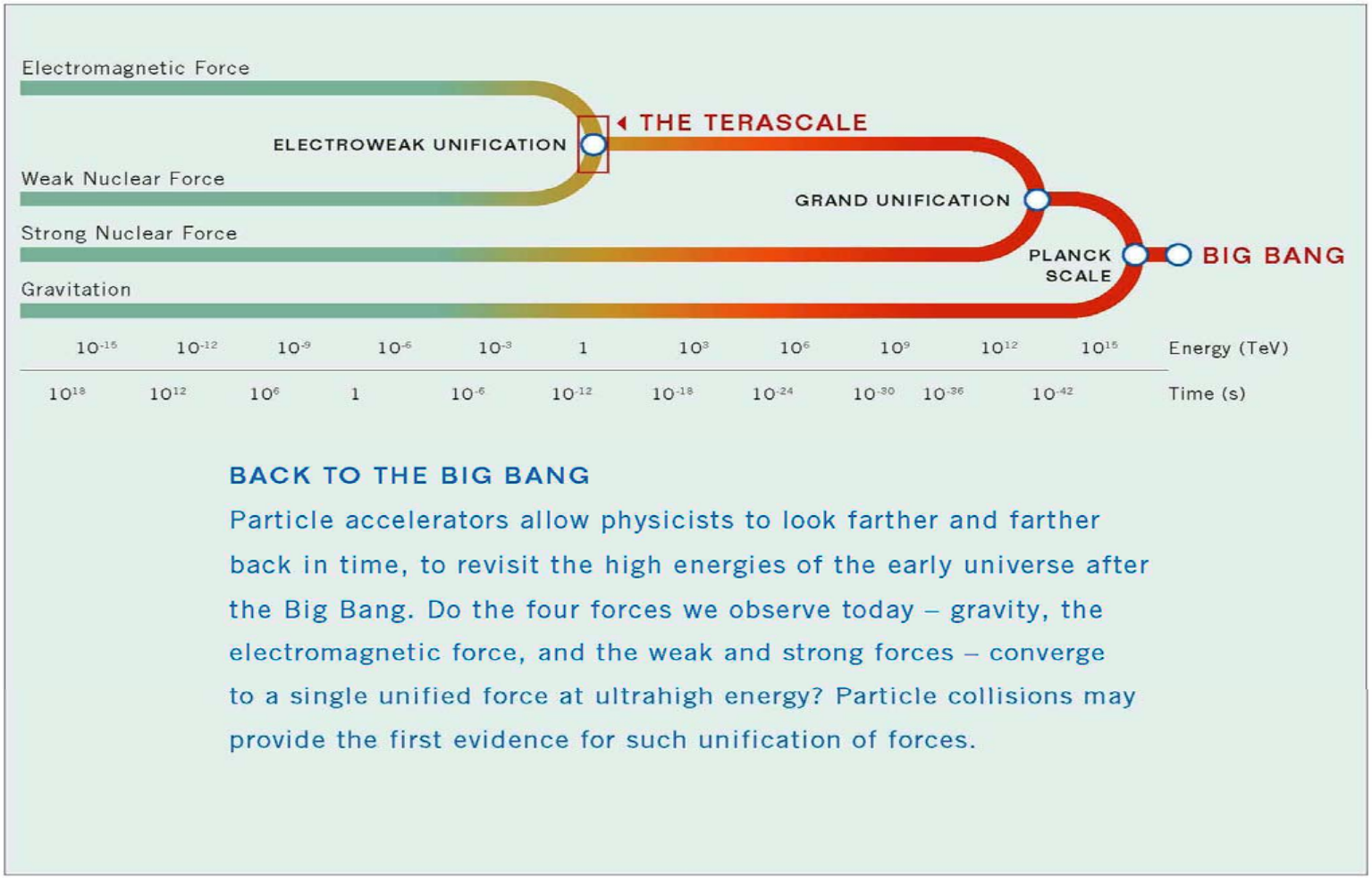


What is matter?

- **Quarks**
  - combine to make protons and neutrons
- **Leptons**
  - eg. electron, neutrino
- **Force Carriers**
  - defines behavior of matter



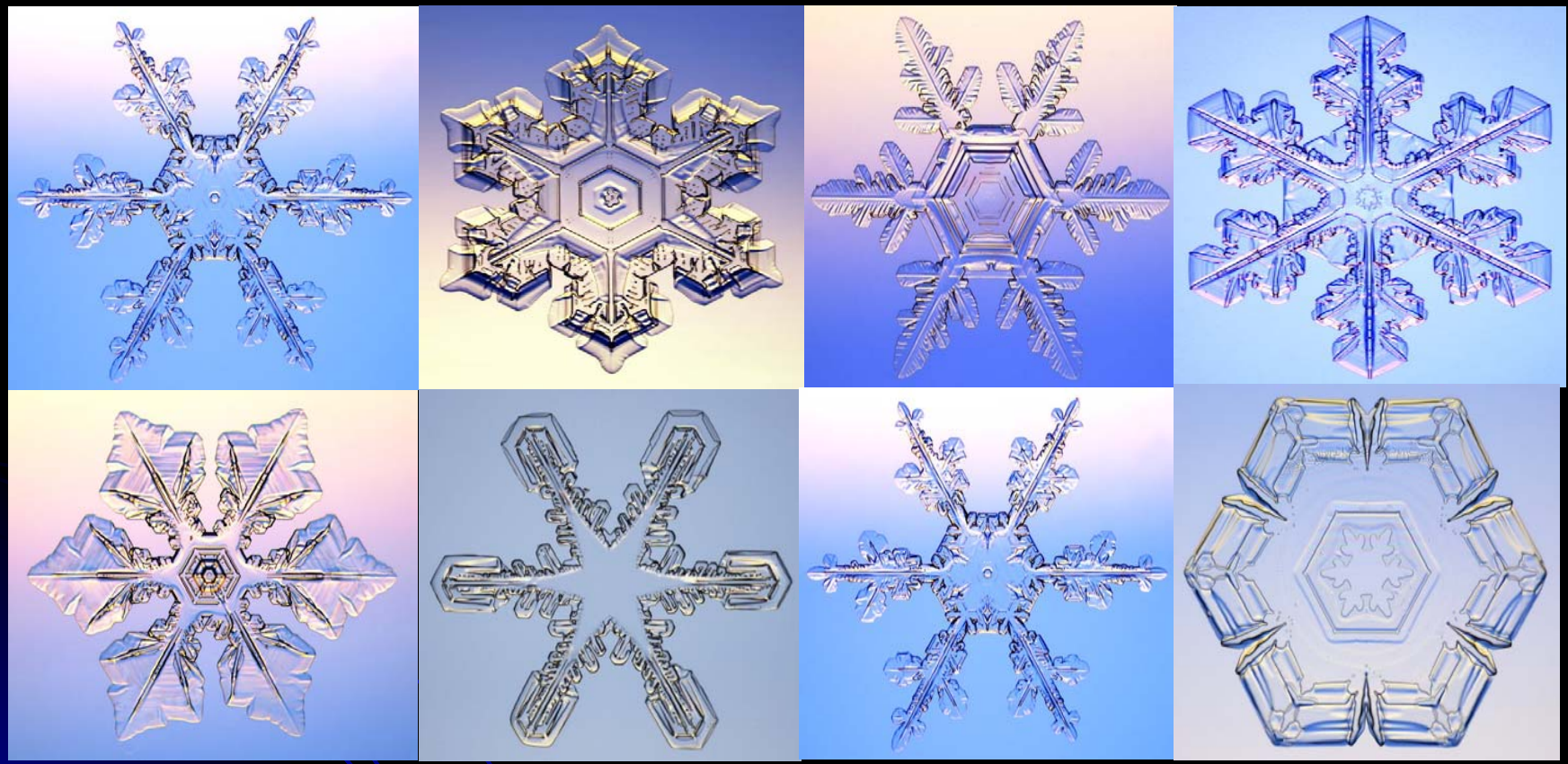
How does this hang together?



BACK TO THE BIG BANG

Particle accelerators allow physicists to look farther and farther back in time, to revisit the high energies of the early universe after the Big Bang. Do the four forces we observe today – gravity, the electromagnetic force, and the weak and strong forces – converge to a single unified force at ultrahigh energy? Particle collisions may provide the first evidence for such unification of forces.

Underlying simplicity?

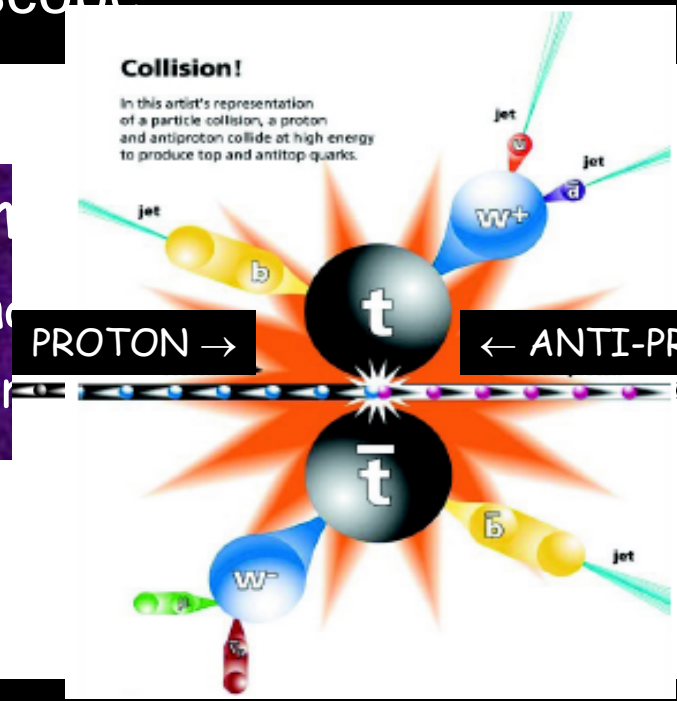


Particle Accelerato

- probe laws of the cosmos in 2 ways

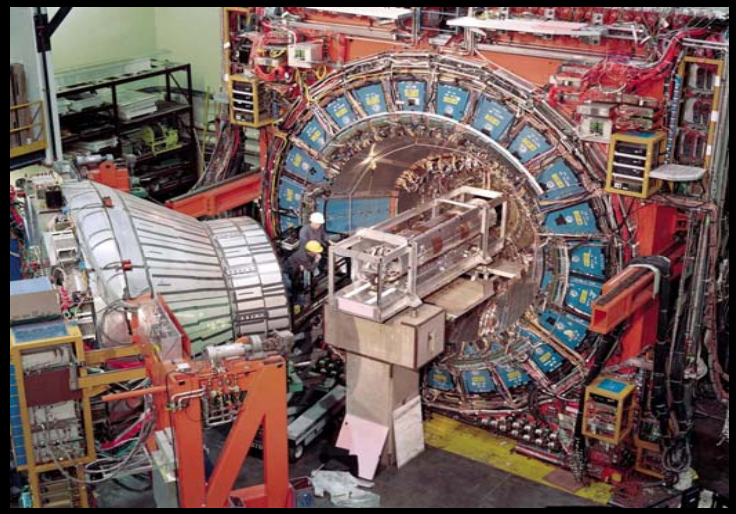
1. Super-microscope

2. Creation of n
   - Heavy ordin
   - Dark Matte



Tevatron Program

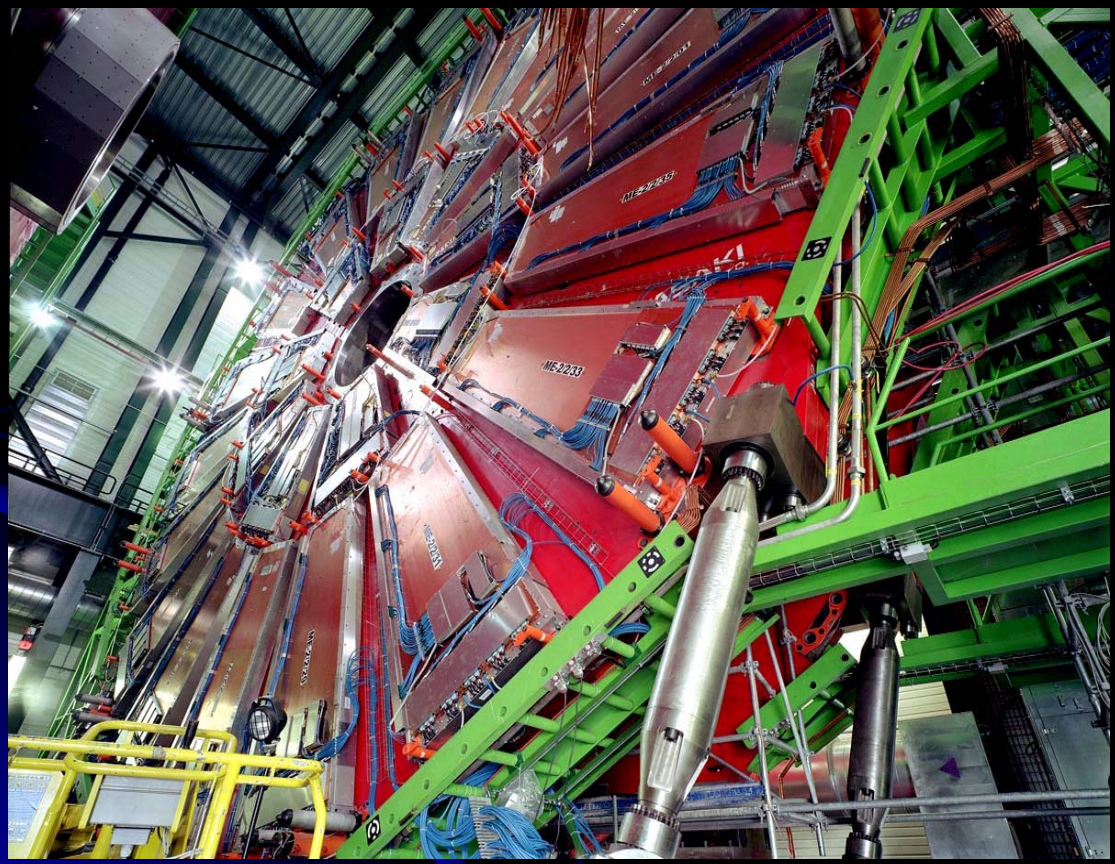
- Greatest window into new phenomena until LHC is on
- 1500 collaborators, 600 students + postdocs
- Critically dependent on Luminosity
- Doubling time a major consideration



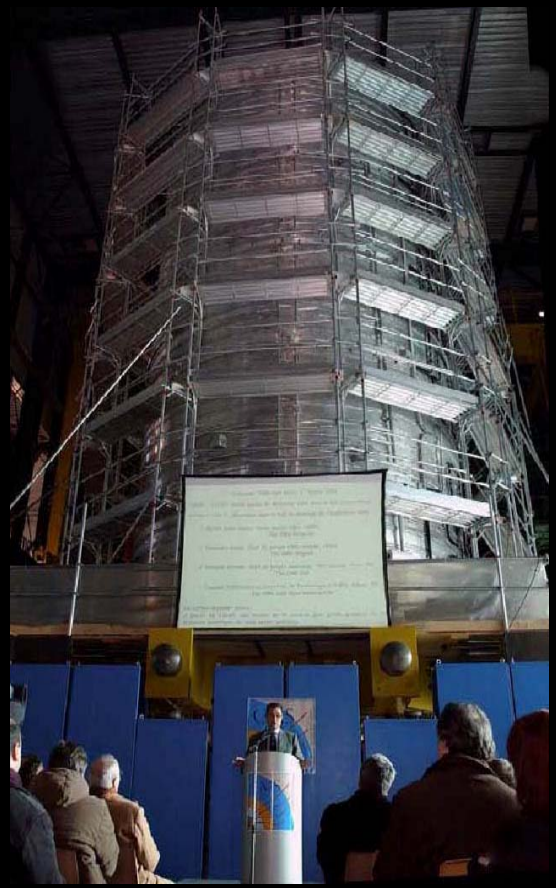
Large Hadron Collider (LHC)
Geneva, Switzerland

CMS: Compact Muon Detector

- Coming together: aimed at completion by end of 2007



Muon detectors



Magnet cold mass

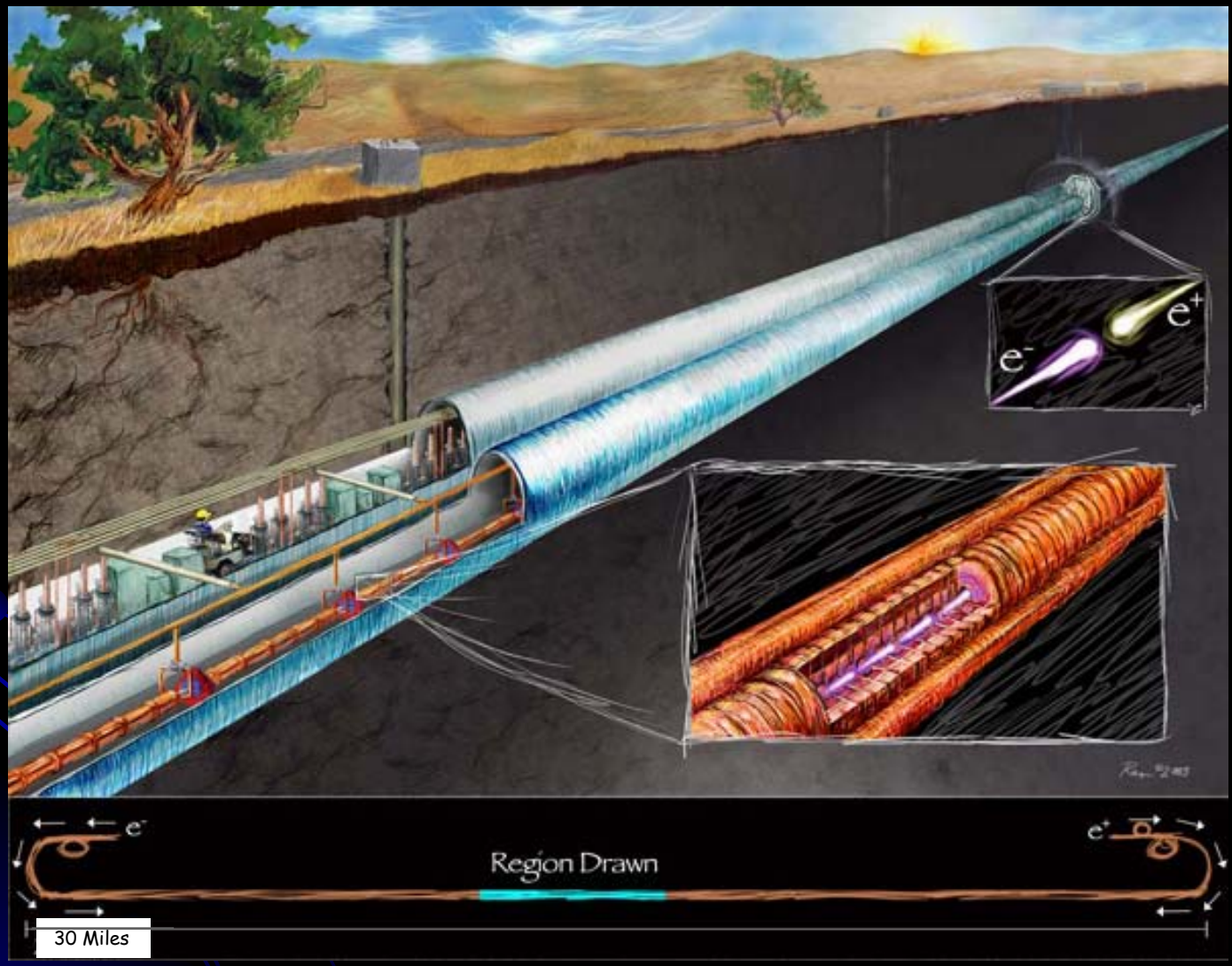
CMS: Compact Muon Detector

- US collaboration doubled in the last three years

>300 Collaborators

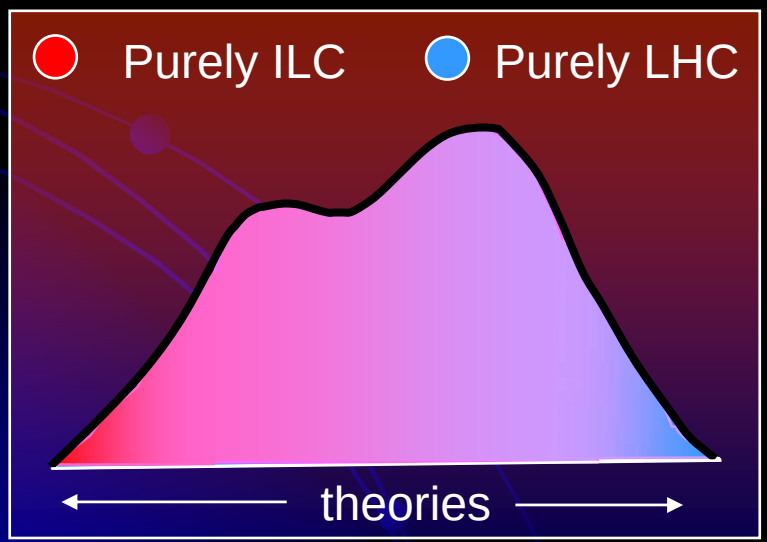
41 Institutions

First Priority for the future: International Linear Collider (ILC)



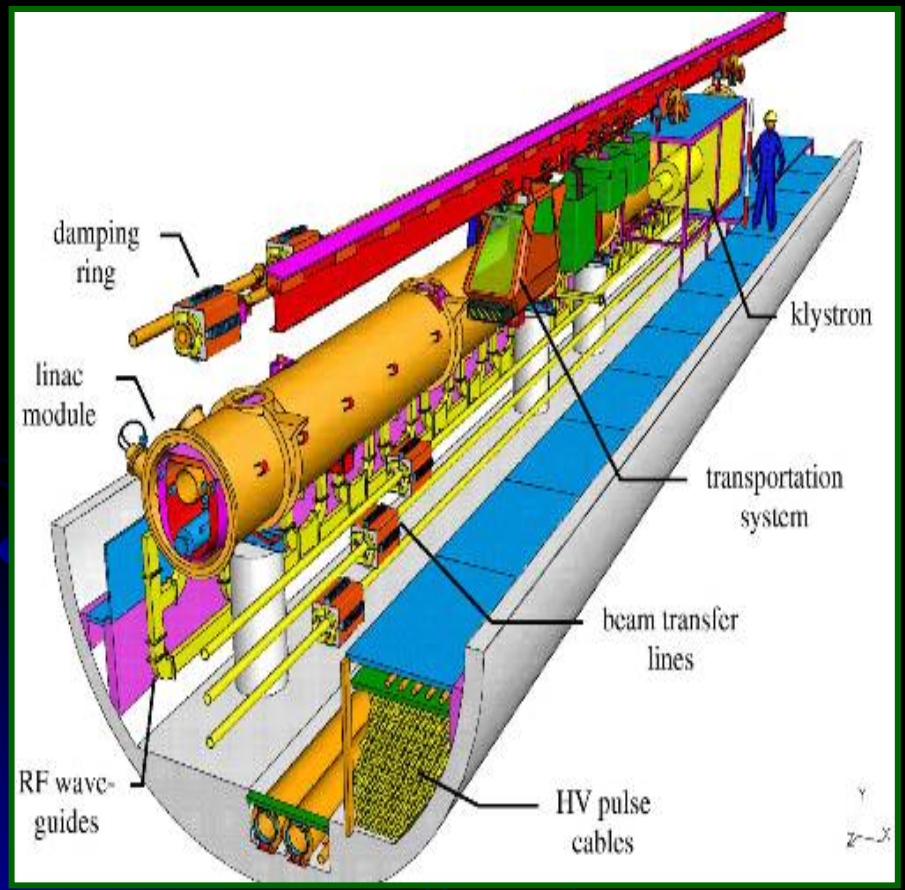
Physics at the Energy Frontier

- We expect the greatest richness at the energy frontier
- Few phenomena will manifest themselves in only one machine LHC or ILC



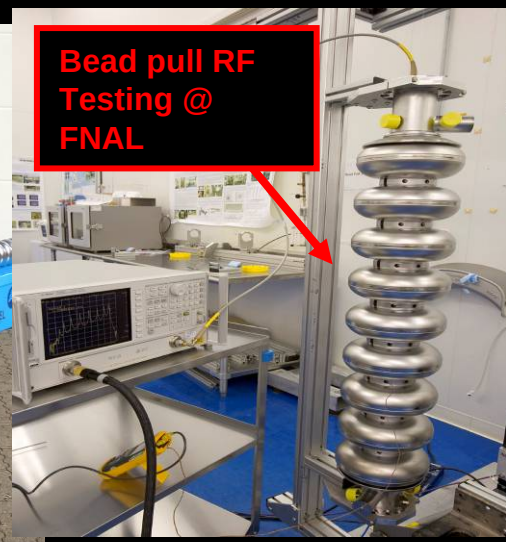
- We will build on the foundation of LHC to make major discoveries at ILC

ILC Machine Design



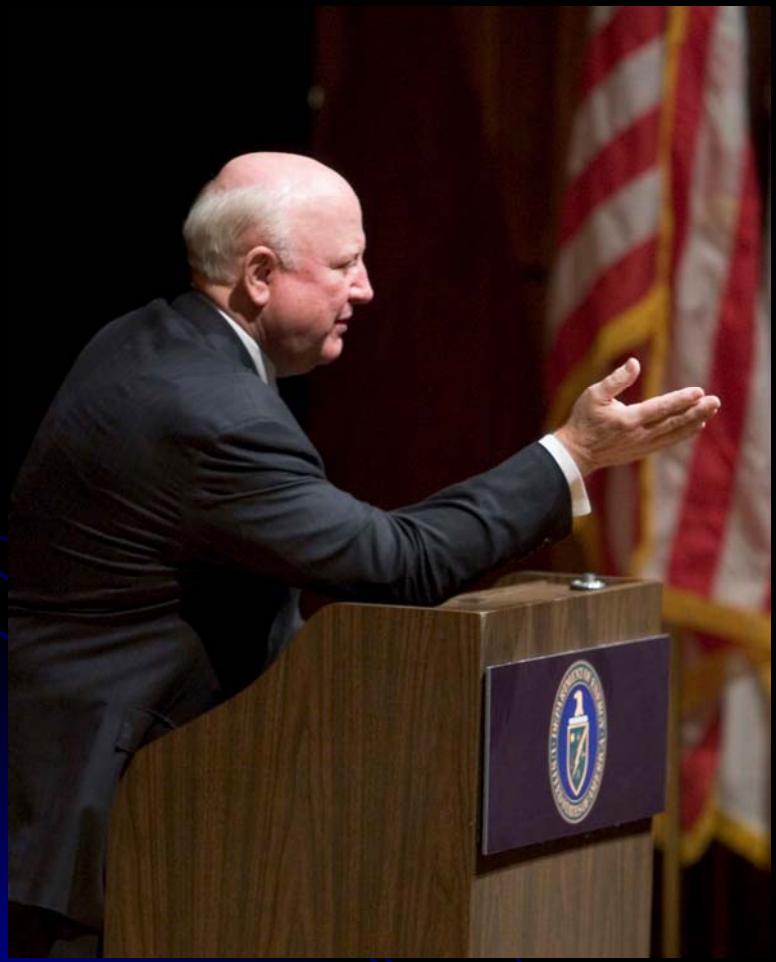
- Fermilab has focused its R&D efforts on the ILC Main Linacs. Broad collaboration.
- Main Linac activities:
  - Accelerator physics design
  - Demonstrate feasibility of all Main Linac technical components
  - Engineering design of ML technical systems
  - Estimates of the ML cost & methods for cost reduction
  - U.S. Industrialization of high volume ML components

ILC 1.3 GHz Cavities @ FNAL



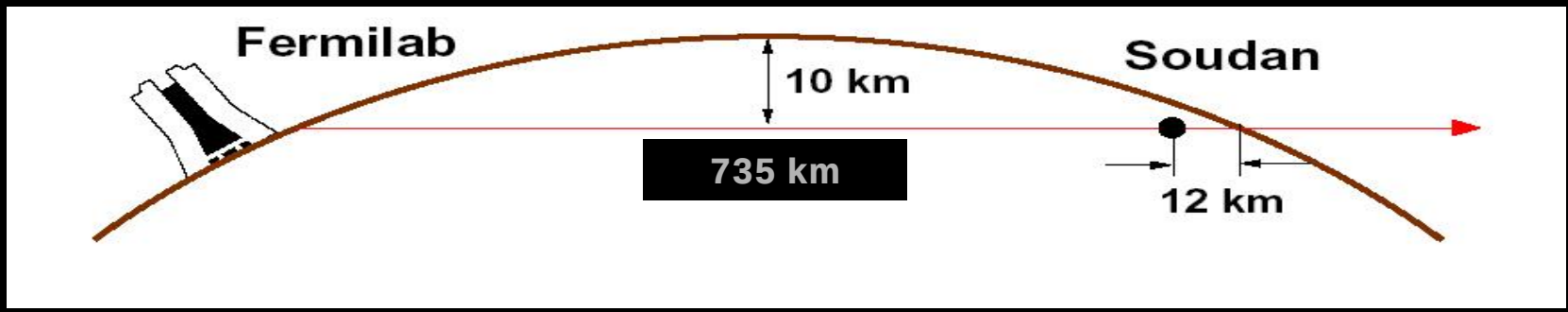
- Industrial fabrication of cavities, some in U.S. Industry
- Two Single/large Crystal cavities under development with TJNL
- BCP and vertical testing at Cornell (25 MV/m)
- EP and vertical testing at TJNL. (35 MV/m)
- Joint BCP/EP facility being developed ANL (2007)
- High Power Horizontal test facilities @ FNAL (2006)
- Vertical test facility @ FNAL (2007)

Key International Process: RDR



- Secretary Bodman: How much …….?
- The RDR is now key element: it determines whether DOE leadership states intent to bid-to-host and makes necessary investment.

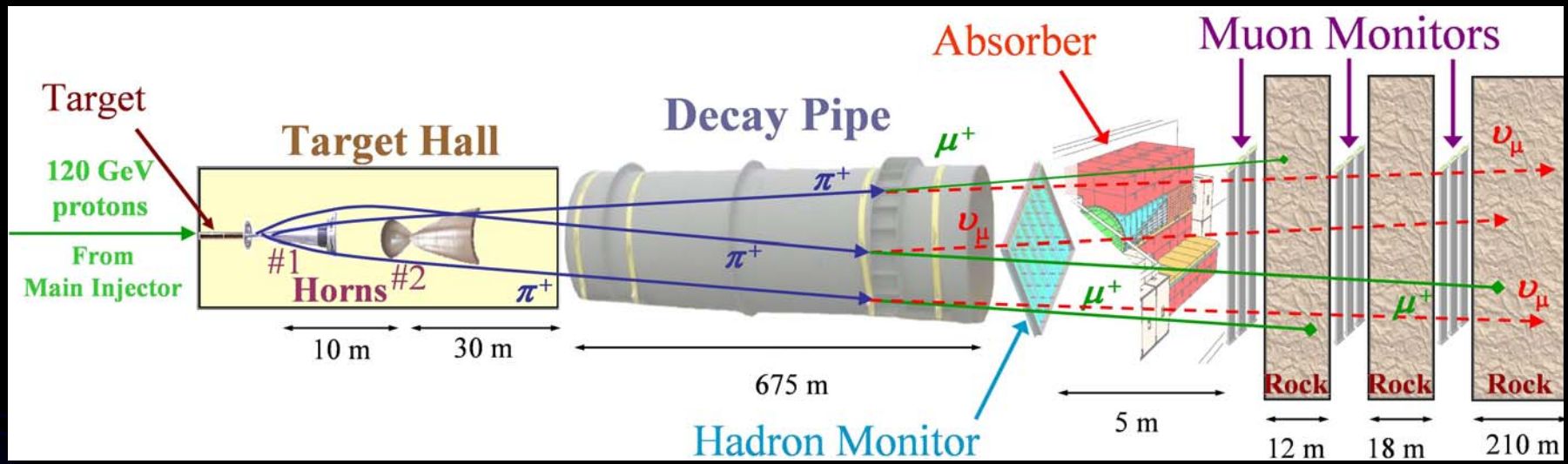
Present Neutrino Program: MINOS



Minos near detector: 1 kton

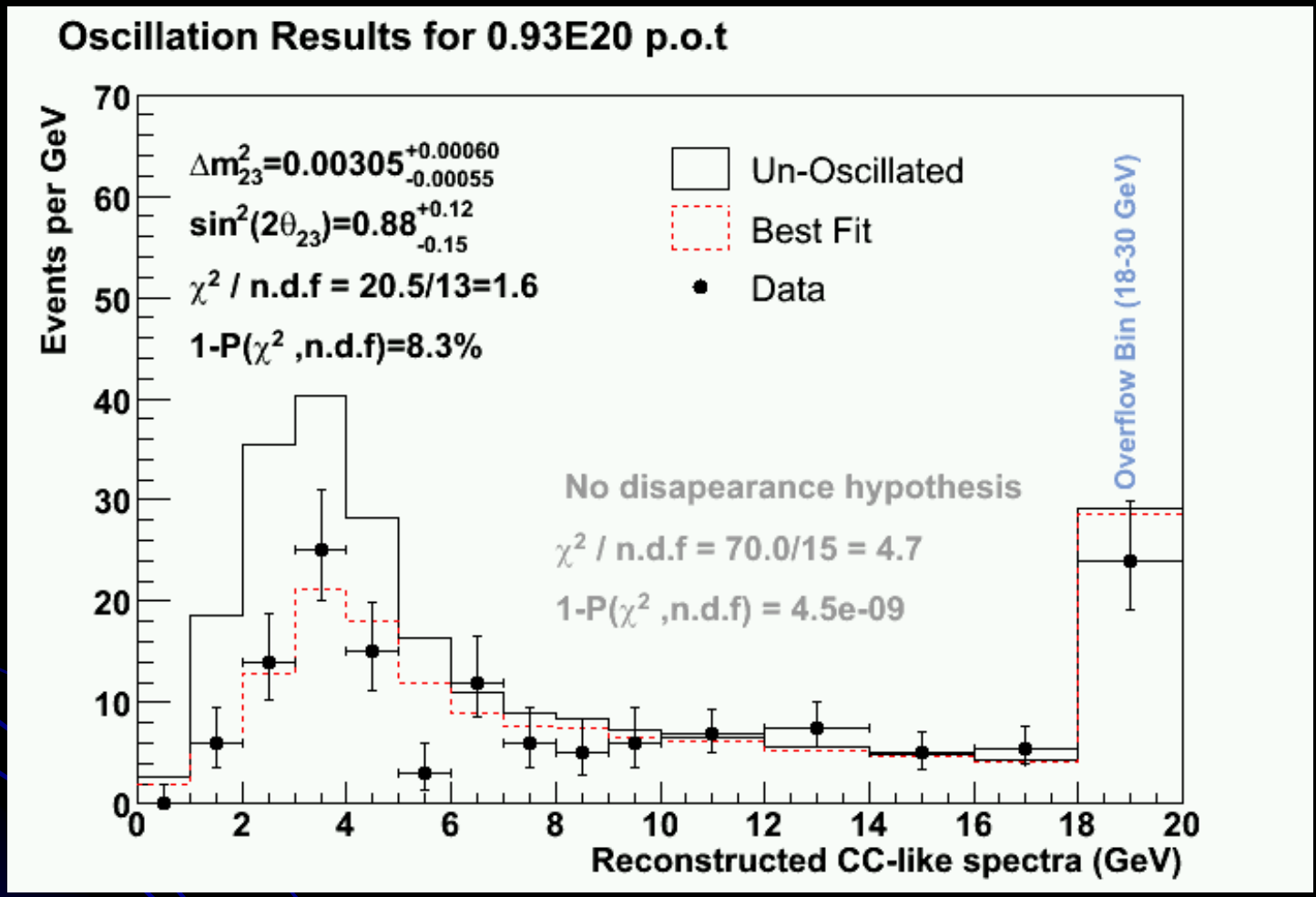
Minos Far detector: 5.4 kton

Producing the neutrino beam



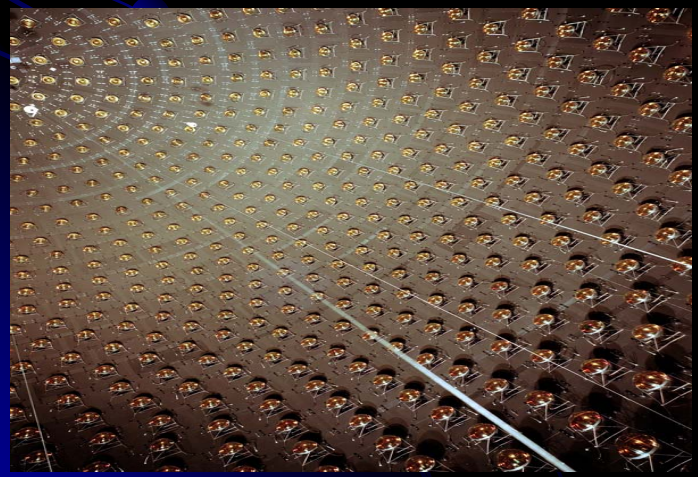
- Moveable target relative to horn 1 – continuously variable neutrino spectrum

Best-fit spectrum



- Measurement errors are 1 sigma, 1 d.o.f.

Present Neutrino Program



- MiniBooNE

  - 1 GeV neutrinos (Booster)

  - 800 ton oil cerenkov

  - Operating since 2003

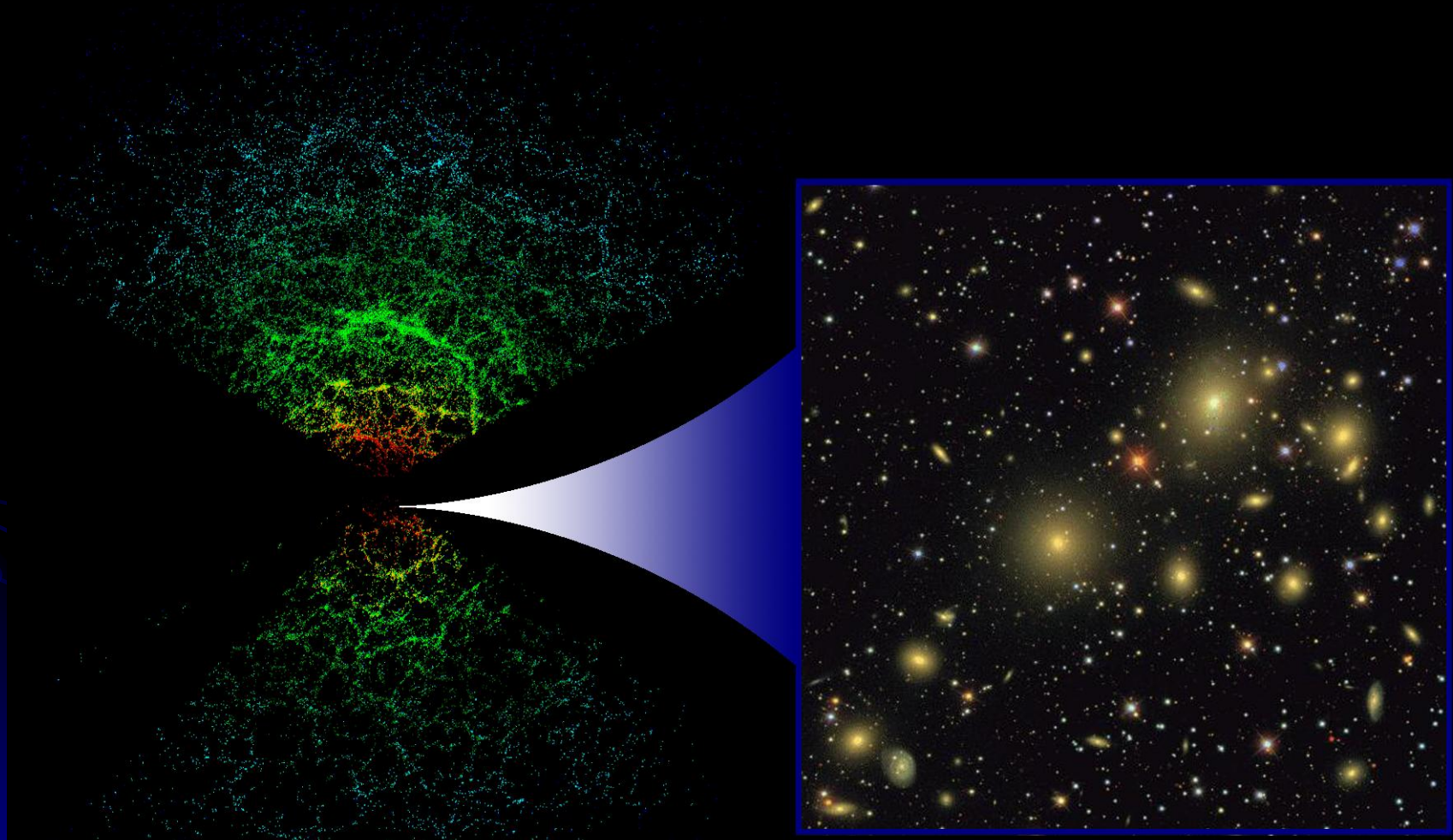
  - $\nu_\mu \rightarrow \nu_e$ appearance

  - first results this fall: all hell will break loose if positive signal

Deep underground and deep in space

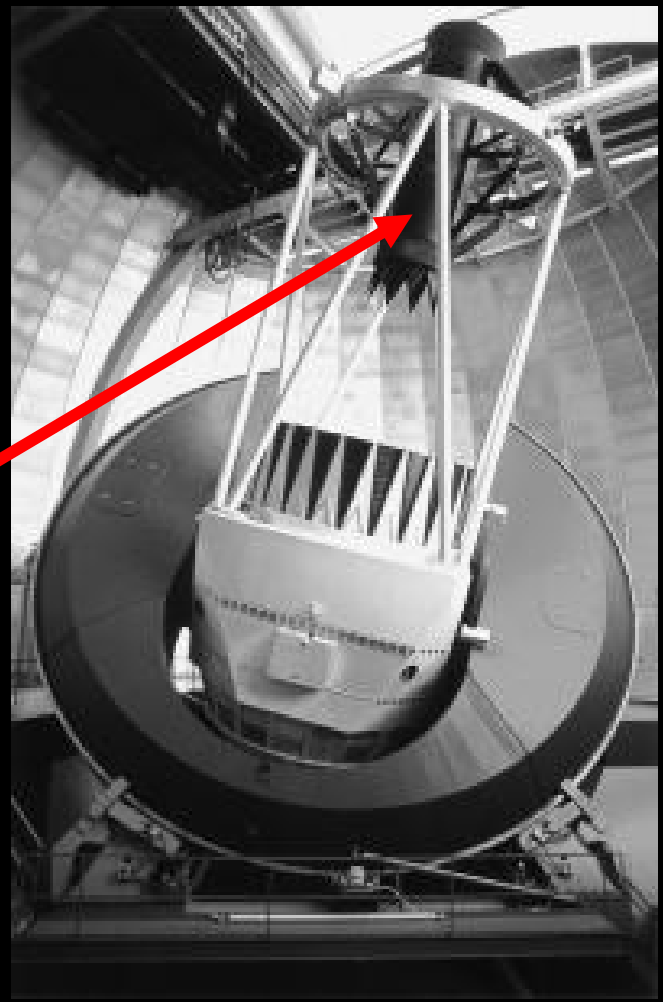
- Principal emphasis is dark matter and dark energy.
- On going projects:
  - Sloan Digital Sky Survey: the study of structure of galaxies and clusters of galaxies
  - CDMS: most precise limits in the world on cold dark matter

Sloan Digital Sky Survey

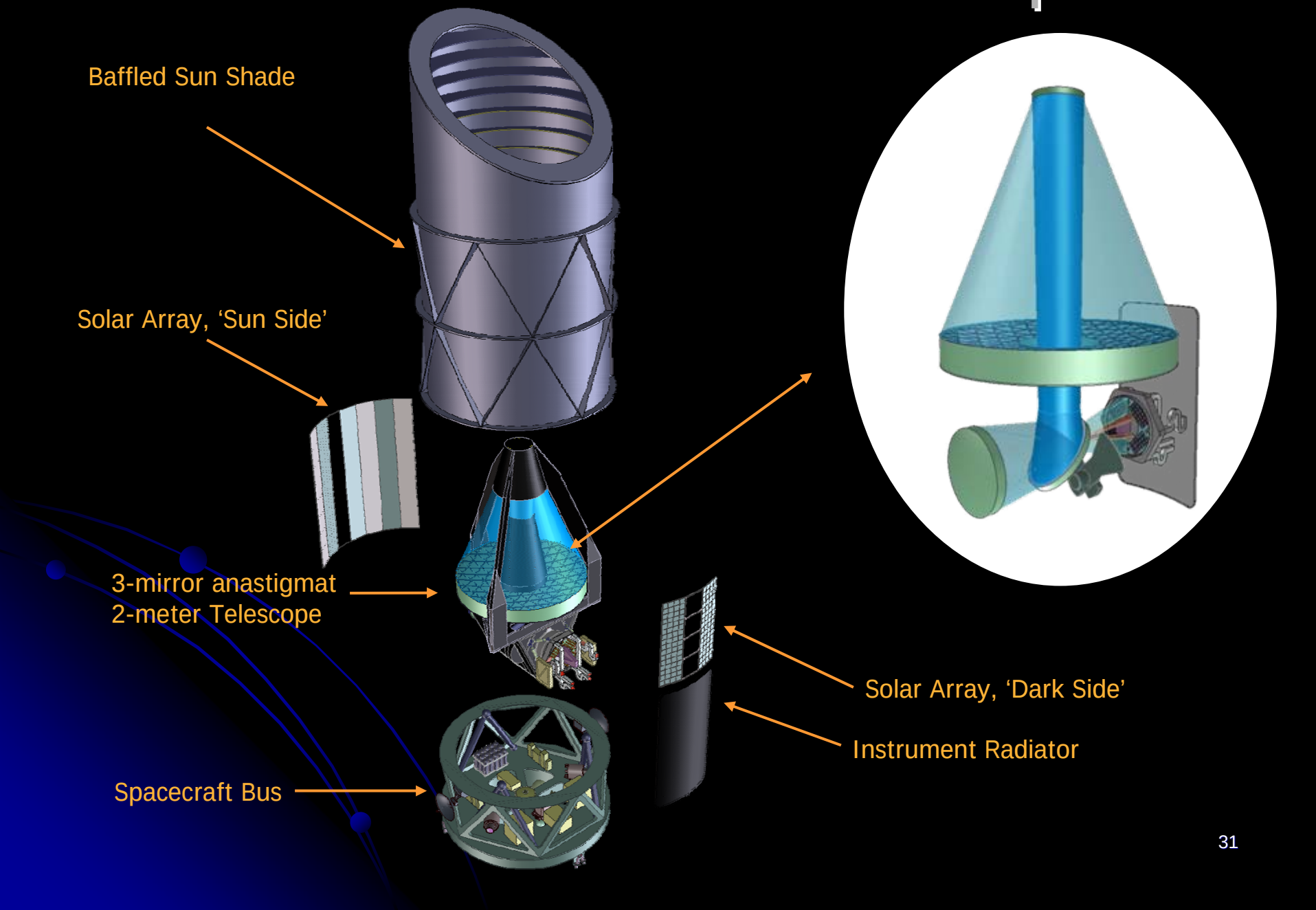


The Dark Energy Survey (DES)

- Proposal:
  - Perform a 5000 sq. deg. survey of the southern galactic cap
  - constrain the Dark Energy parameter w to ~ 5% with 4 complementary techniques
  - begin to constrain dw/dz
- New Equipment:
  - Replace the PF cage on the CTIO Blanco 4m telescope with a new 2.2 deg. FOV optical CCD camera
- Time scale:
  - Instrument Construction 2005-2009
- Survey:
  - 30% of the telescope time from 2009-2013



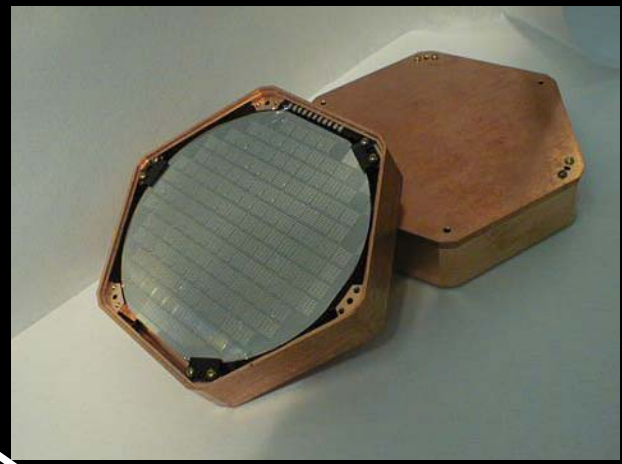
SNAP Instrument Concept

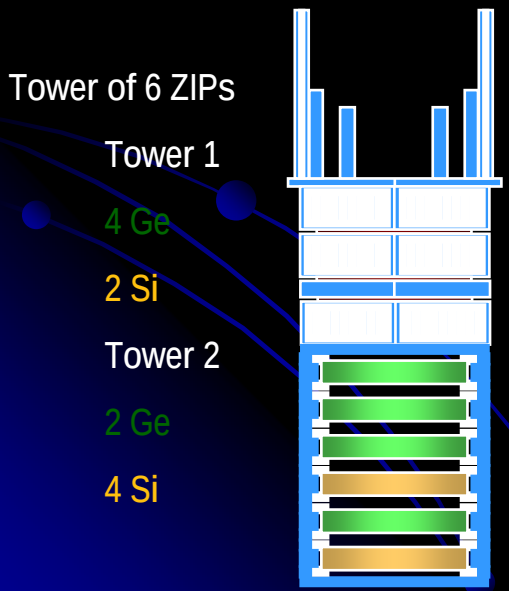


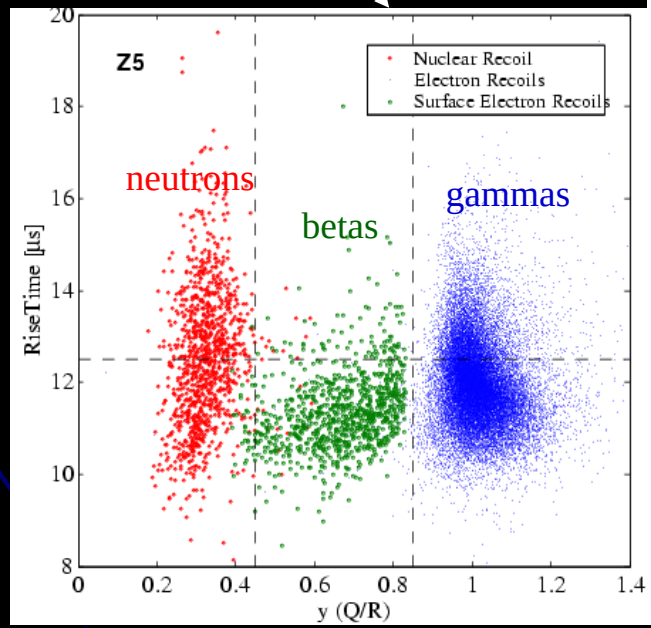
Dark Matter: CDMS

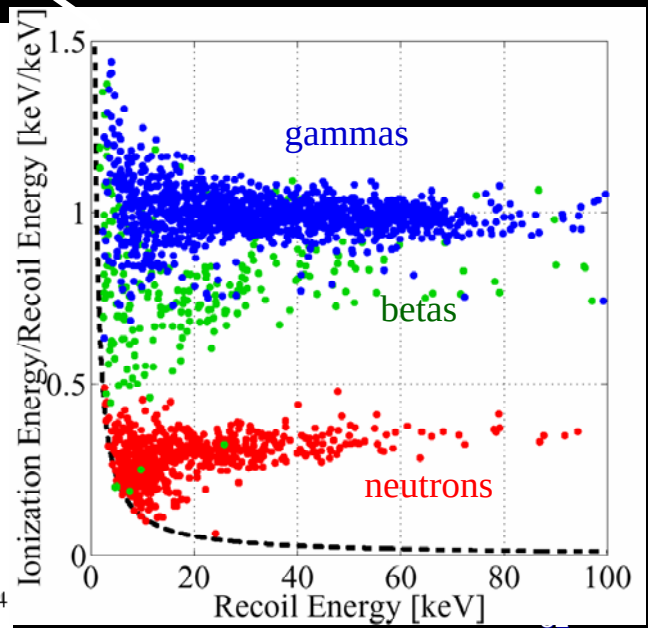
Detectors with excellent event-by-event background rejection

- Measured background rejection:
- 99.995% for EM backgrounds using charge/heat
- 99.4% for β's using pulse risetime as well
- Much better than expected in CDMS II proposal!



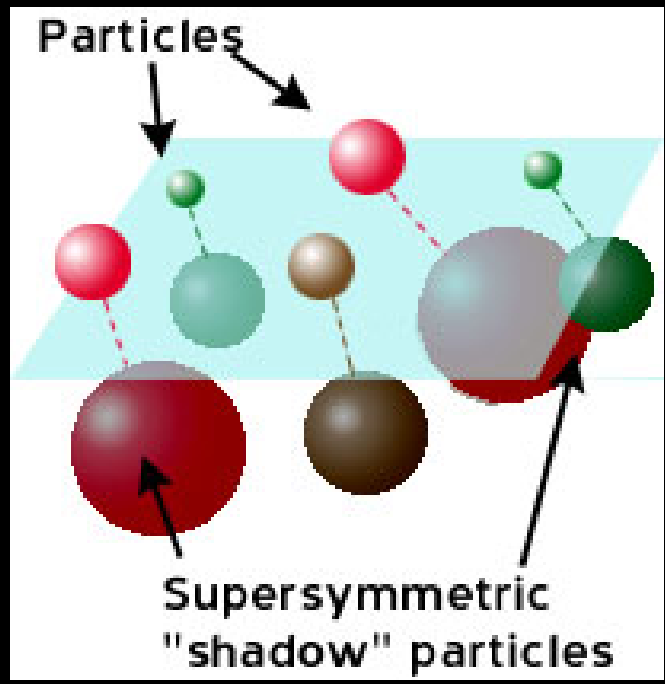


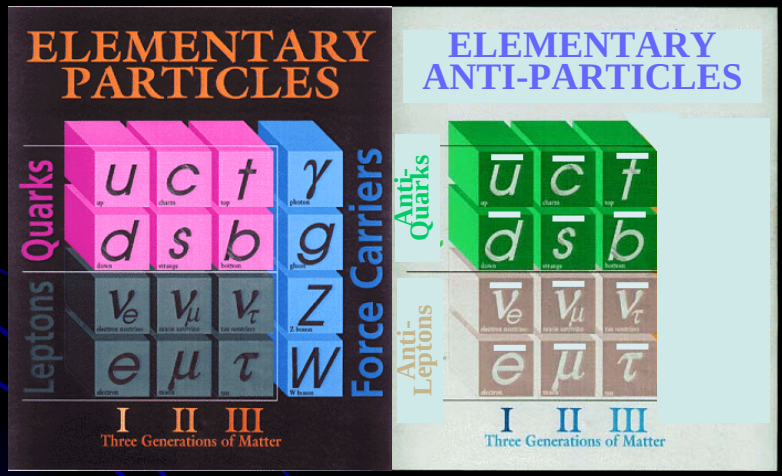




Supersymmetry and Strings

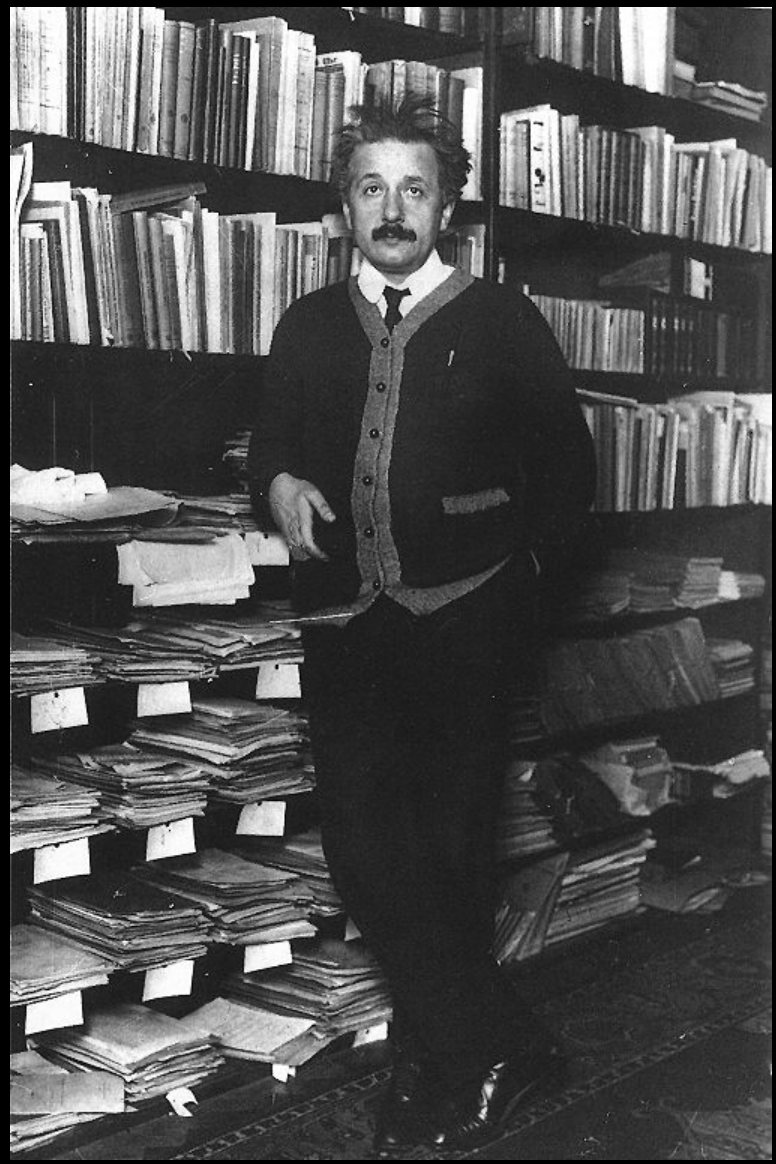
- History repeats?
- Just as for anti-matter,
  - New particles are required to make successful theory





- The supersymmetric particles have just the properties expected of Dark Matter

- The grand aim of all science is to cover the greatest number of empirical facts by logical deduction[2] from the smallest number of hypotheses or axioms.



- When I examine myself and my methods of thought,
- I come close to the conclusion that the gift of fantasy has meant more to me than my talent for absorbing positive knowledge.